CONTROLLING INPUT TORQUE USING A FLYWHEEL IN A SLIDER CRANK MECHANISM

Abstract

Torque in slider crank mechanism fluctuates in a cycle. Choosing Power of motor is based on maximum torque. The maximum of torque only appear in small length of time in one cycle. Using the motor had correlation with maximum torque resulting lose out because the motor just have maximum load in small range of a cycle time. To reduce motor size can be used flywheel. The energy needing more the average energy in a cycle can be supplied by flywheel. In this research the flywheel is used to control torque appearing in mechanism. The assumption in this case study is load acting in mechanism only inertia force. By using flywheel size motor can be reduced about 25%.

1. Introduction

The typically large variation in accelerations within a mechanism can cause significant oscillations in the torque required to drive it at a constant or near constant speed. The peak torques needed may be so high as to require an overly large motor to drive them.

In the fact, Torque in one cycle of rotate crank is not constant. Varies of torque is caused by variation of accelerations in mechanism. To design the fly wheel is needed value of average torque in over cycle which it (due mainly to losses and external work done) is often smaller then the peak torques.

The smooth torque and small size motor can be provided by flywheel. Energy supplying when crank is on external work done position so the flywheel will be absorbed it.

1.1 Boundary of Problems

In this research. The Flywheel is used to control torque appearing in slider crank mechanism. Torque in mechanism is only caused by inertia force and friction in contact of body is neglected.

1.2 Methodologies of Research

The research is based in literacy study. Steps of analysis are kinematics analysis, then continued by dynamics analysis. Dynamics behavior of mechanism such as inertia force and torque appearing in crankshaft is based on dynamics analysis. The last steps is calculate dimension of flywheel based on amount of energy available for a cycle.

2. Literature Studies

Energy absorb by fly wheel

Figure 1 shows a fly wheel designed as a flat circular disk, attached to a shaft of motor which might also be driven shaft for the crank.

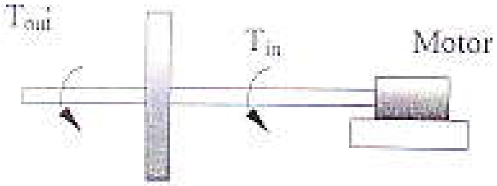

Figure 1 Positioning of flywheel on crankshaft

The motor supplies a torque magnitude T_{in} having constant value to be equal to average torque. The load in other side of flywheel, demands T_{out} which varying depend on characteristics of load. The energy in rotating system is

$$E = \frac{1}{2} I\omega^2 \quad (1)$$

Where I is moment of inertia of all rotating mass on the shaft. This includes, the I of the motor rotor and of the link crank plus that of the flywheel. Moment inertia, I is determined to reduce of flywheel speed rotation of the shaft to an acceptable level. By using Newton's Law:\

$$\sum T = I\alpha \quad (2)$$

$$T_{out} - T_{in} = I\alpha \quad (3)$$

But needed T_{in} equal with $T_{average}$

$$T_{out} - T_{average} = I\alpha \quad (4)$$

Angular acceleration, can be explained as $\alpha = \omega \frac{d\omega}{d\theta}$

$$T_{out} - T_{average} = I\omega \frac{d\omega}{d\theta} \quad (5)$$

$$(T_{out} - T_{average})d\theta = I\omega d\omega \quad (6)$$

Integrating equation (6)

$$\int_{\theta @ \omega_{min}}^{\theta @ \omega_{max}} (T_{in} - T_{out}) d\theta = \int_{\omega_{min}}^{\omega_{max}} I\omega d\omega \quad (7)$$

$$\int_{\theta @ \omega_{min}}^{\theta @ \omega_{max}} (T_{in} - T_{out}) d\theta = \frac{1}{2} I(\omega_{max}^2 - \omega_{min}^2) \quad (8)$$

The left side of expression equation (8) represents the change in energy between the maximum and minimum rotation speed of shaft. The right side is the change in energy stored in the flywheel.

Dimension of The Fly Wheel

Dimension of flywheel disk is depended on amount of energy absorbed. Absorbing energy produced by fluctuating speed rotation in form kinetic energy. Fluctuation of speed rotation can be explained with coefficient of fluctuation, K

$$K = \omega_{max} - \omega_{min} \quad (9)$$

The coefficient K can be normalized by dividing it by the average of speed crank shaft

$$K = \frac{\omega_{max} - \omega_{min}}{\omega_{average}} \quad (10)$$

The K coefficient is a design parameter to be chosen by designer. It typically is set to a value between 0.01 and 0.05, corresponding to a 1 to 5% fluctuation in shaft speed.
Energy of kinetic on equation (8) is amount of energy absorbed by flywheel expressing by

$$E = \frac{1}{2} I\left(\omega_{max}^2 - \omega_{min}^2\right) \quad (11)$$

By using factorize equation (11) can be explained by

$$E = \frac{1}{2} I(\omega_{max} + \omega_{min})(\omega_{max} - \omega_{min}) \quad (12)$$

and speed rotation average is shown by

$$\omega_{average} = \frac{\omega_{max} - \omega_{min}}{2} \quad (13)$$

with result equation (11), (12) and (13) can be got

$$E = \frac{1}{2} I(2\omega_{average})(K\omega_{aveage}) \quad (14)$$

and

$$I = \frac{E}{K\omega_{average}^2} \quad (15)$$

Inertia moment of flywheel can be explained with

$$I = \frac{W}{g} r^2 \quad (16)$$

Where r indicate radius of gyration of flywheel.

3. Analysis of Kinematics and Dynamics Mechanism

Flywheel is needed to reduce the peak torque caused by inertia force in slider crank mechanism. Dimension of mechanism is shown in Table 1.

Table 1. Dimension and weight of link

No	Link	Dimension (cm)	Weight (kg)	Inertia mass (kgm^2)
1	Crank	10	1	0.01
2	Coupler	60	1.5	0.025
3	Slider	-	1	0.05

Center mass each link is on the middle of link.

The Assembling of mechanism is shown in Figure 2.

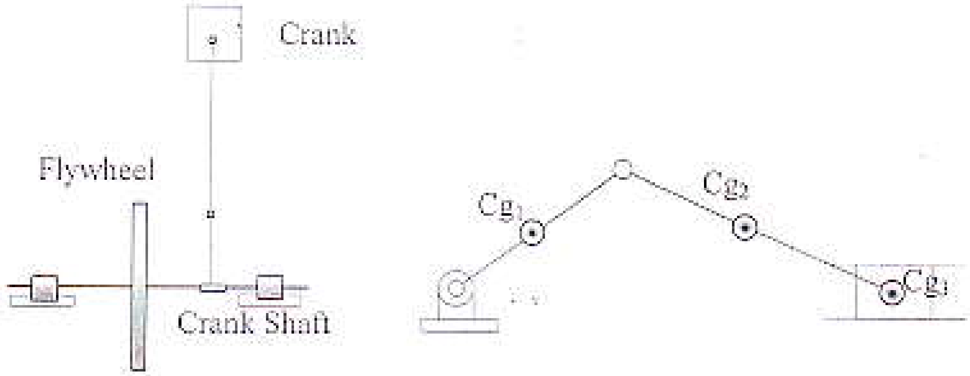

Figure 2 Slider Crank and Flywheel

Assumption using in analysis is only inertia forces doing in mechanism. Dynamics and kinematics analysis on the slider mechanism is explained in this report. Kinematics analysis on the mechanism included position, velocity and acceleration analysis. The position of slider is shown in figure 3

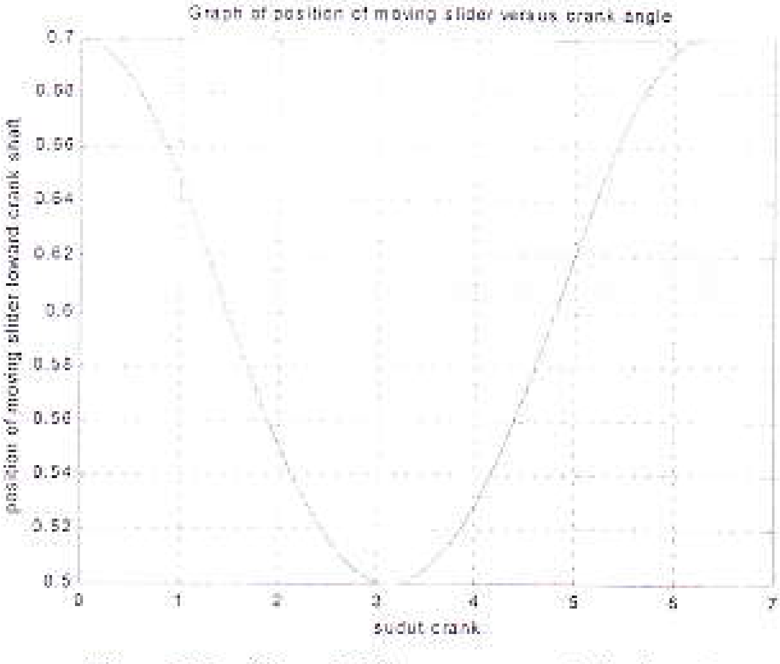

Figure 3 Position of slider versus crank shaft angle

Minimum of distance between crank shaft and center gravity of slider is 0.5 m having relation with 3.14 rad of crank shaft angle. The velocity and acceleration analysis of slider are shown in figure 4 and 5.

Figure 4 Velocity of slider versus crank shaft angle

Negative of velocity indicate direction of moving slider explaining slider move to near of crank shaft. The minimum and maximum velocity (-10 and 10 m/s) became when crank angle is about 1.71 and 4.71 rad.

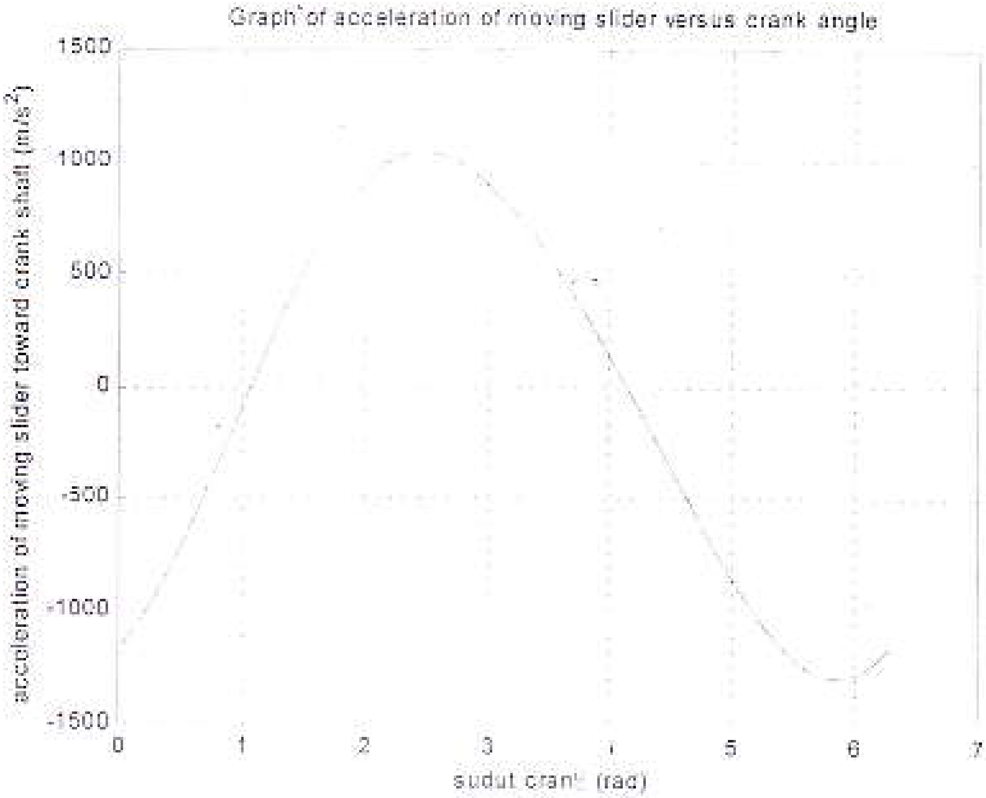

Figure 5 Acceleration of slider versus crank shaft angle

Value of acceleration of center gravity of slider is between 1043 and −1043 m/s^2. The maximum value of acceleration is 1043 m/s^2 becoming on 2.5 rad of crank angle.

To analyze the dynamics force of mechanism is needed acceleration of center gravity of each link. The acceleration is depicted in figure 6.

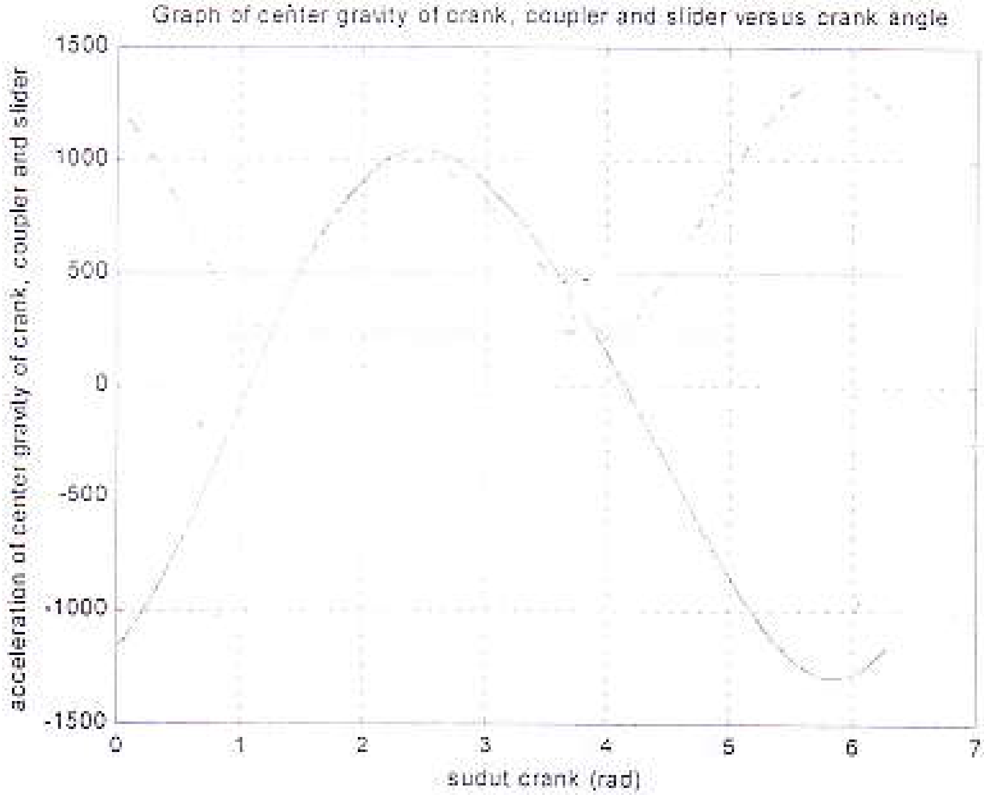

Figure 6 Acceleration of center gravity of crank, coupler and slider versus crank angle

Bold line (-), solid (-) and dashed (--) indicate acceleration of center gravity of crank, coupler and slider

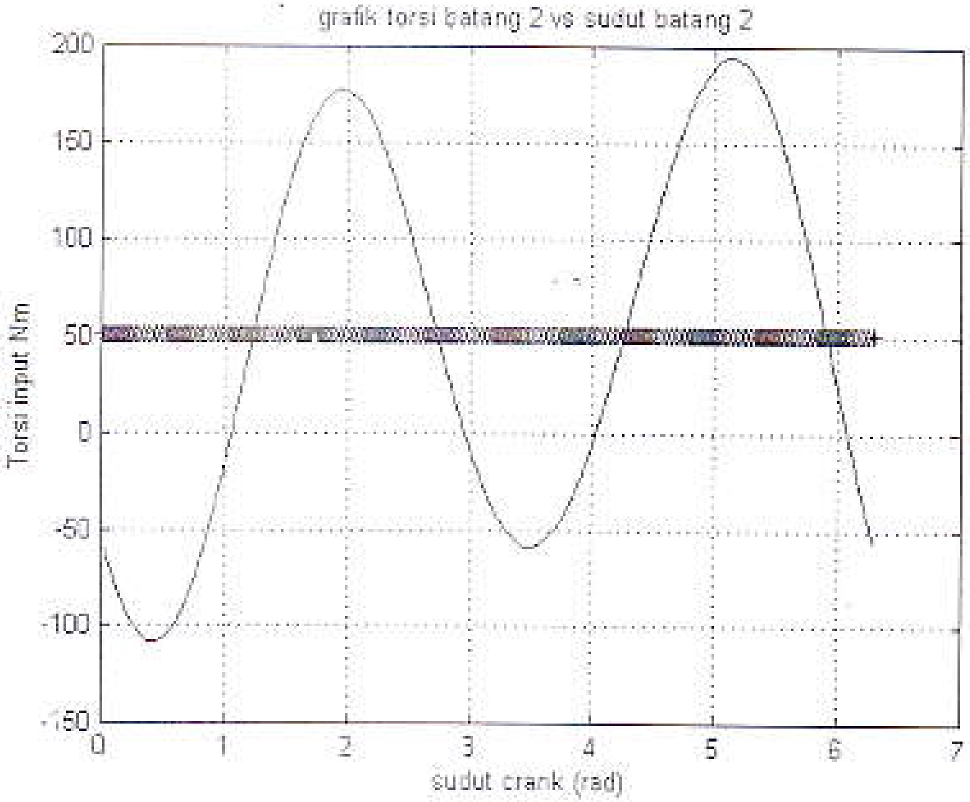

Figure 3 Torque input and average in crank

The maximum energy suppiying in a cycle is got by integrate energy above average torque. From the figure 3 can be shown that average torque a cycle is 50 Nm. The average torque is counted by integrating the curve of input torque in mechanism.

The maximum energy absorb by flywheel is area of torque curve which is bounded by ω_{max}, ω_{min} and average of torque. The input torque in figure (3) can be redrawn in figure (4) by moving zero torque to average torque.

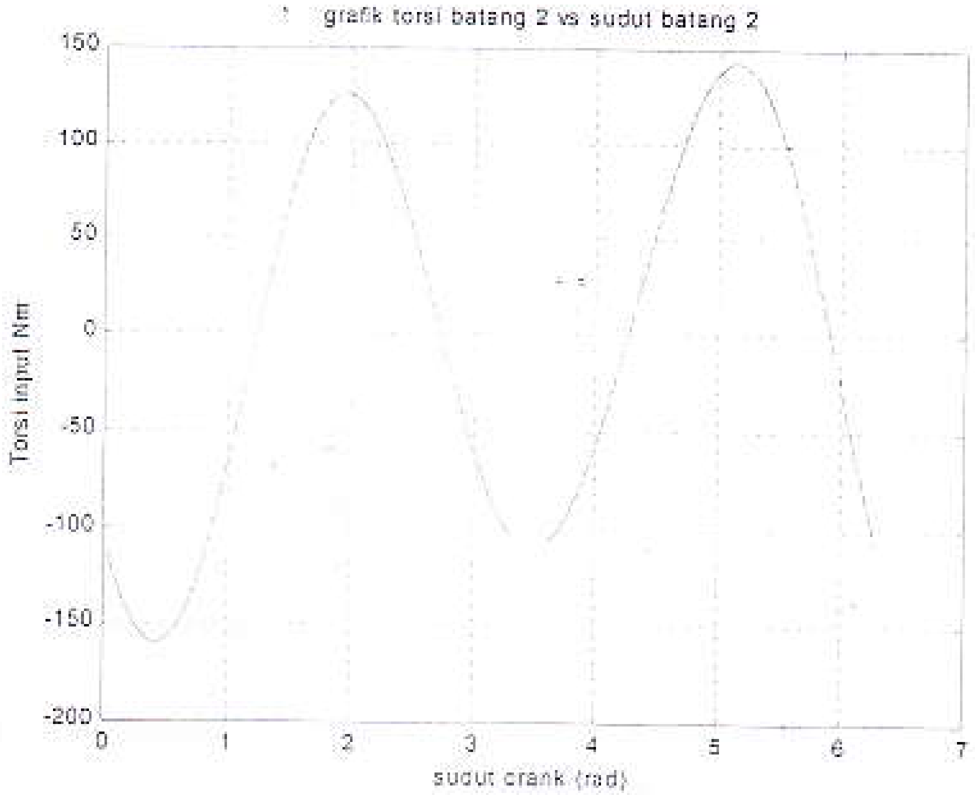

Figure 4 Torque input in mechanism after decreasing to average torque

The changing of maximum energy is bounded by angle crank, 4.2 and 5.91 rad. The energy can be counted by integrating area of torque curve in figure (4) which its value is 150, 2 Nm.

Calculating of flywheel dimension

Dimension of flywheel can be got by using equation (15) and another paramerer using to find dimension of flywheel is shown in Table 2.

Table 2 Property dynamics of mechanism

No	Kind of parameters	Value
1	Coefficient of Fluctuation, k	0.01
2	Speed rotation of crank shaft, $\omega_{Average}$	100 rad/s
3	Energy absorb by flywheel, E	150.2 Nm
4	Radius gyration of flat flywheel	0.5 m

From the value of parameter in Table 2, and by using equation (15), dimension of flywheel can be calculated

$$I = \frac{E}{K\omega_{average}^2} = \frac{150.2}{0.01 \cdot 100^2} = 1.502\ kg\,m^2$$

and mass of flywheel is calculated with equation (16)

$$m = \frac{I}{r^2} = \frac{1.502}{0.5^2} = 6\ kg$$

The motor power needing to supply torque to crankshaft can be calculated by using next question equation

$$P = \frac{T \cdot n}{9550}$$

If mechanism without flywheel so motor power needing is

$$P = \frac{194.65 \cdot 60 \cdot 100}{9550 \cdot 2\pi} = 19\,HP$$

but in other hand by using flywheel so motor power is

$$P = \frac{50 \cdot 60 \cdot 100}{9550 \cdot 2\pi} = 5.1\ HP$$

4. Conclusion

Using flywheel can be controlled torque appearing in mechanism. Energy that must be supplied by motor can be reduced about only 25% from energy supplying to mechanism without flywheel. Motor only supply torque equal with average torque in a cycle.

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